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NATIONAL BUREAU OF STANDARDS REPORT

8574

THERMAL CONDUCTIVITY OF
FIVE EPOXY RESIN SPECIMENS

by

T. W. Watson and H. E. Robinson

Report to

Sandia Corporation
Albuquerque, New Mexico

NBS

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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Thomas W. Watson and Henry E. Robinson

1. INTRODUCTION

This report presents results of thermal conductivity measurements in the temperature range 20 to 133 °F of five samples of epoxy resin base submitted by the Sandia Corporation, Sandia Base, Albuquerque, New Mexico. The samples are intended for use as thermal conductivity reference standards by the Sandia Corporation. The measurements at NBS were authorized by Sandia Contract Number 16-2276, dated 18 June 1964.

2. SPECIMENS

Five different epoxy resin samples were submitted for measurement, each in the form of a pair of specimens each approximately 9 inches by 9 inches by 1 inch in size.

When received ~~8~~ 14 August, the pairs of specimens were designated by the numbers 1 through 5 inscribed on the edges of each respective piece and were further identified by letter of 4 September as follows:

1. 89.3% (weight) Shell 828 epoxy resin
   10.7% Diethanol amine (DEA)
   Cured at 160 °F for 15 hours 40 minutes on 6 July 1964

2. 69.6% 828 resin
   22.0% mica filler
   8.4% DEA
   Cured at 160 °F for 16 hours 30 minutes on 7 July 1964

3. 44.6% 828 resin
   50.0% mica filler
   5.4% DEA
   Cured at 160 °F for 18 hours 15 minutes on 8 July 1964

4. 71.4% 828 resin
   20.0% mica filler
   8.6% DEA
   Cured at 160 °F for 66 (sic) hours on 10 July 1964

5. 62.5% 828 resin
   30.0% mica filler
   7.5% DEA
   Cured at 160 °F for 17 hours on 13 July 1964.

The specimens also were described as having been cast by Sandia as 9-inch by 9-inch by 1-1/8-inch pieces. The 1-1/8-inch thickness was then ground to be approximately one inch in size as submitted. It is noted here that the detailed descriptions of the specimens given on Page 1 of Contract No. 16-2276 differ from those given above.

3. METHOD AND PROCEDURE OF TEST

The thermal conductivity measurements were made in an 8-inch guarded hot-plate apparatus (conforming to ASTM C177) having a 4-inch square central metering section. The tests were conducted in a cabinet in air maintained at within about two degrees Fahrenheit of the specimen mean temperature; the exposed edges of the specimens protruded 1/2-inch beyond the hot and cold plates of the apparatus and were covered by about 1 inch of fine glass-fiber insulation.

Because of the low thermal resistance, and rigidity, of the specimens the tests were made using a composite-specimen technique* to minimize thermal contact problems, and which avoided need for thermocouples applied to the specimen faces. A resilient pad (1/8-inch commercial gum rubber, 30 to 45 Durometer floating stock, Federal Specification MIL-R-880A) was interposed between each face of the specimen and the adjacent metal hot or cold plate of the apparatus at a pressure of approximately 50 lb/ft^2, so that there was on each side of the hot plate a composite specimen consisting of pad, specimen, pad. The total temperature drop through the composite specimen was measured by means of the permanent thermocouples installed in grooves in the metal faces of the cold and hot plates. The test yielded as its result the average thermal resistance per unit area of the two composite specimens over the central 4-inch square area. By subtracting from the average composite-specimen resistance the average thermal resistance of the two rubber pads at the same mean temperature, as determined in separate tests using the same permanent plate thermocouples, the average net thermal resistance of the principal specimens was calculated. The average thickness (apparent thickness) of the principal specimens during test was determined by subtracting from the measured value of the distance between the cold plates during the composite-specimen test the measured distance between the cold plates determined in the separate tests at the same mean temperature, in which the rubber pads alone constituted the test specimen.

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*See ASTM C177-63, paragraph 4(h)

In the separate tests of the two pairs of 8-inch by 8-inch by 1/8-inch gum rubber pads the thermal resistance increased linearly with temperature from a value of 0.240 deg F/(Btu/hr ft^2) at 20 °F to 0.252 at 130 °F, with none of the six values obtained departing by as much as 0.2 percent from the linear relationship. Similarly, the average total thickness of the two rubber pads measured in the apparatus increased linearly from 0.247 inch at 20 °F to 0.255 at 130 °F, with no departure exceeding 0.2 percent.

4. RESULTS AND DISCUSSION

The results of the thermal conductivity measurements are summarized in Table 1. A plot of thermal conductivity versus density at about 130 °F is shown in Figure 1; the conductivity of these specimens varied smoothly with density.

As shown in Table 1, two tests at about the same mean temperature were made on Specimen No. 1. At the conclusion of the first test (HC90164) there was no visible warping of the specimens in the apparatus, nor was there a significant thickness change during the test. However, after leaving the specimens stacked together on a table overnight it was discovered the following day that the specimens had become concavo-convex in shape. The concave face of each specimen was the face that had been toward the hot-plate in the conductivity test. Because of the dishing, which amounted to about 0.5 millimeter at the center, the specimens were compressed between flat metal plates under a load of 124 pounds for seven days. After this period, there was no perceptible change in the degree of concavity. Nevertheless, a repeat test (HC92564) was made on the specimen by the composite technique, with the specimens reversed so that the previously-colder side (now convex) faced the hot plate, in the hope that the test temperature gradient might reduce the dishing. Actually, the degree of dishing increased slightly during the test. As Table 1 shows, the final apparent thickness of the specimen in the second test was 0.017 inch greater than in the first test, indicating a degree of dishing too extreme to be accommodated by the rubber pads. Consequently, the conductivity result obtained in this test (1.40) is not valid (is low), and is recorded only as a matter of interest.

Because of the warping of Specimen No. 1 after the first test, no further valid conductivity measurements could be made with it at lower temperatures. Fortunately, perceptible warping did not occur for any of the other specimens, and it was feasible to make all of the desired measurements on them, as recorded in Table 1. The slight changes in thickness with temperature recorded in Table 1 appear to indicate an effect of thermal expansion, but the precision of the specimen thickness determination is not enough to afford a clear indication, although it is believed adequate to indicate that warping was not appreciable for the last four specimens.

No information is available to us as to the effect of aging or elevated temperatures on the thermal conductivity of these materials. It is believed that any change in the conductivity of the material would be relatively unimportant as compared to the effects of warping of the specimen which might result from aging, insofar as the use of the specimens as references is concerned. Because of the rigidity of the specimens, and their high conductances, plate surface thermal contact resistances arising either from imperfect flatness of contacting surfaces or warping of the specimen can introduce serious errors in their use as references. The composite-specimen technique used in these measurements was adopted to minimize such errors, and it is believed was successful in this direction in the tests of Specimens Nos. 2 to 5, and in the first test of Specimen No. 1. Equal avoidance of thermal contact errors is of course necessary in using these specimens as thermal conductivity references.

TABLE 1

Summary of NBS Tests on Five Epoxy Resin Specimens

Specimen No.	Test No.	Mean Temperature of Specimens °F	Thermal Conductivity Btu/hr ft^2(F/in.)	Thickness* Inch	Density* lb/ft^3	Temperature Gradient in Specimens deg F/in.
1	HC90164	131.0	1.50	0.978	74.5	29.9
1	HC92564	132.2	[1.40]**	.995	73.2	31.8
2	HC90464	25.3	2.34	0.978	84.7	22.7
2	HC90864	71.1	2.35	.979	84.6	22.6
2	HC90964	131.6	2.41	.979	84.6	22.0
3	HC91064	20.5	4.67	1.000	103.1	11.9
3	HC91164	66.1	4.68	1.001	103.0	11.9
3	HC91464	128.4	4.75	1.001	103.0	11.8
4	HC91564	26.7	2.21	0.984	83.1	25.1
4	HC91864	72.4	2.25	.985	83.0	24.7
4	HC92164	132.8	2.29	.986	82.9	24.4
5	HC92264	25.0	2.80	0.988	89.1	20.4
5	HC92364	70.4	2.84	.989	89.0	20.1
5	HC92464	129.8	2.91	.988	89.1	19.7

*Apparent as tested

**Result not valid; see Discussion

THERMAL CONDUCTIVITY OF EPOXY RESIN SPECIMENS VERSUS DENSITY AT ABOUT 130° F

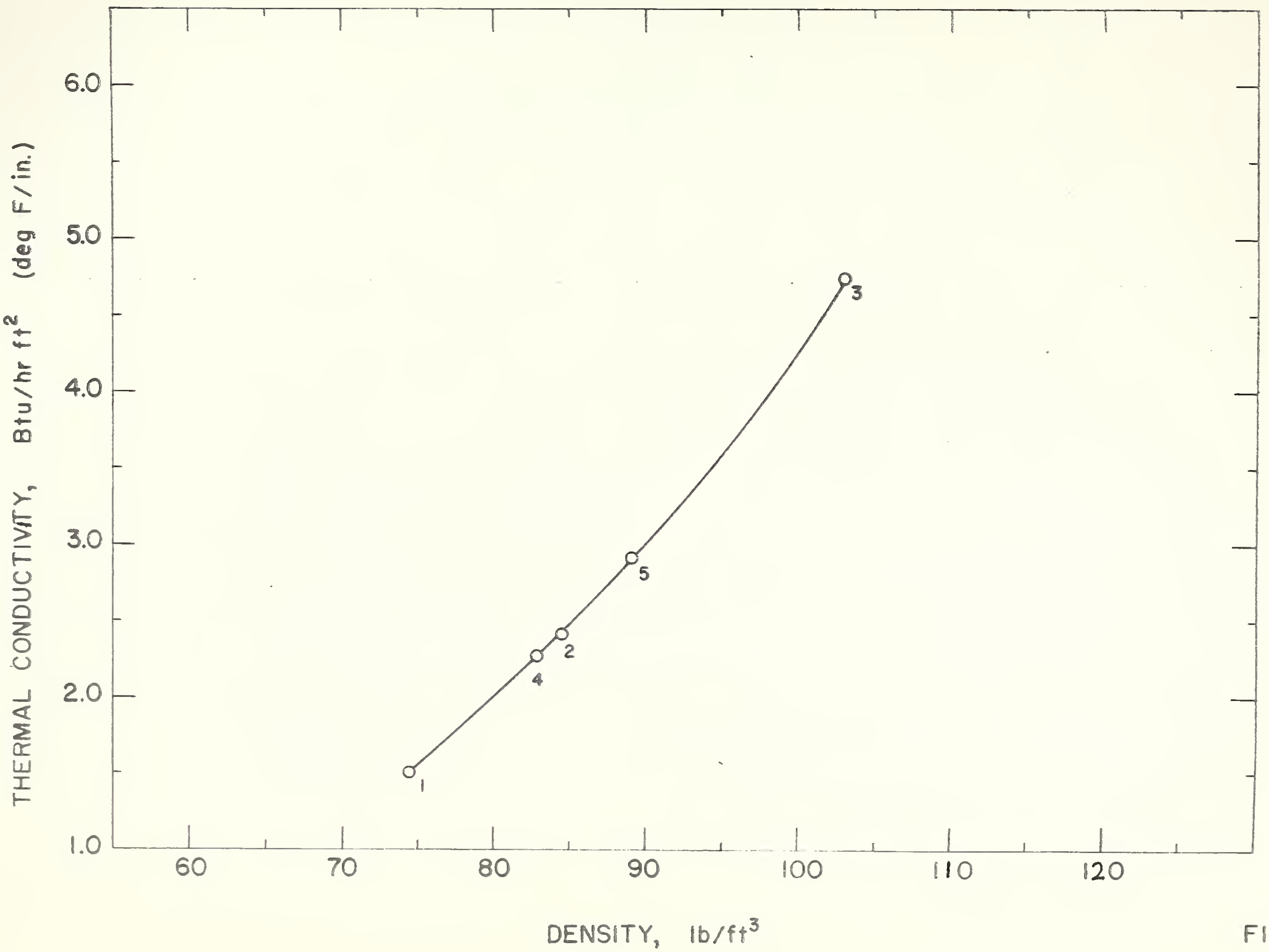

FIG. 1

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